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Textile Structures Modeled on a Spider's Net

Abstract

Innovative textile fabrics modelled on the structure of a spider web can find application in the reinforcing of composites in conditions of where a centrifugal force occurs, for example rotational discs. At the Institute of Architecture of Textile at the Technical University of Łódź research work is carried out on mechanised production of woven fabrics whose structure is modelled on a spider web. The paper presents a review of textile techniques and technologies from the point of view of their usefulness for producing fabrics of a flat round net type structure modelled on the structure of a spider web. There is also an analysis of the mechanical properties of the different textile structures from the point of view of fulfilling the requirements to operate in conditions which are affected by a centrifugal force.

Key words: innovative textile fabric, spider web, textile nets composites, centrifugal force.

Introduction

Web – like constructions are well-known and applied in many fields [5, 6, 11], for example, in the fishery industry, in agriculture, horticulture, transport, sport, medicine, architecture textiles, etc. Although they comprise different structures and involve interesting techniques, as well as different raw materials, the form of nets are always the same in all the above- mentioned fields of net application. In the majority of cases these kinds of nets are characterised by similarity of eye in the product. Most often the sides of the eyes have the same length.

The studies on innovative textile structures like nets are carried out at the Institute of Architecture of Textile at the Technical University of Łódź.

The oldest known natural openwork structure made of linear elements is a spider web. Flat spider's webs are shown in *Figure 1* [16]. The characteristic feature of this structure is a radial arrangement of one of the linear systems. The second linear system is made of concentric polygons. The similarity to woven fabric makes possible to name the radial arrangement of the linear elements – the warps, and the concentric polygons – the wefts. A spider's web is made of elements (eyes) that have a certain shape. These shapes are joined according to the geometrical similarity rule. These elements differ in size, but because of the analogy with woven fabrics, they make a kind of a report of the net.

One may expect that a construction made of thread based on a flat spider's web may possess some interesting features, especially the ability to carry radial forces. These features depend on the single thread properties, their position on the

web or net and the way they are connected with each other.

The connection should be understood as any kind of mutual fixation of threads or other kinds of linear element in the places of their crossing, which forms part of the structure. Such specific textile products may find application in:

- the reinforcement of composites used in centrifugal force conditions (e.g. grinding wheels, cut-off wheels, rotors, etc.) [3],
- the reinforcement of cylindrical constructions (helmets, mazers, bowls etc.).

The main application of nets in the form of a spider's web construction may be in

whirl composite structures as for example cut-of wheels (grinding wheels) (discs). So far, classical nets with gauze weave have been used for material reinforcement. However, such a structure does not cope well with obliquely directed forces. It is expected that the radial arrangement of the elements in a net of the spider web type will solve the problem of barring the forces.

The process of the composite grinding wheels production requires the impregnation of a reinforcing system with resins of high adhesion to the binding material which joins the abrasive grains [7]. That is why the process of net creation should be directly associated with the process of

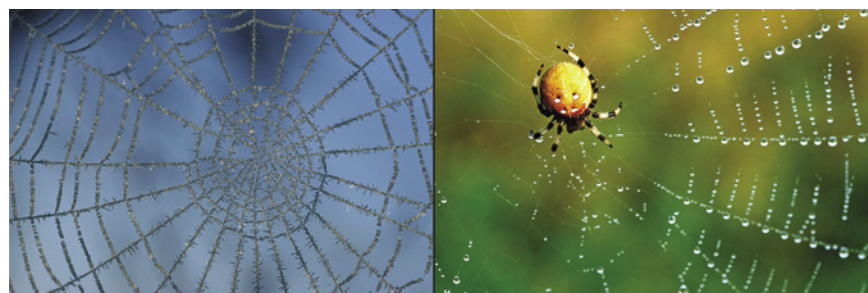
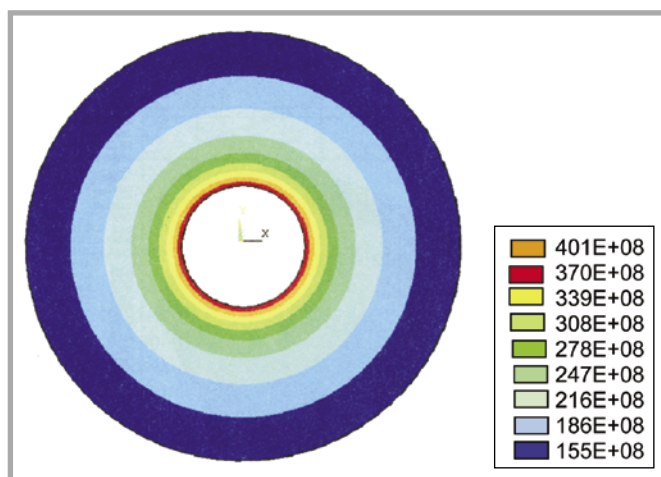


Figure 1. Spider's webs in nature [16].

Figure 3. Distribution of reduced tensions in a 38A 80L7 VBE grinding wheel with diameters of 150 mm and 20 mm and thickness of 40 mm when the maximum angular velocity is $\omega = 1808 \text{ s}^{-1}$ [1].



composite production. Due to the slenderness of the nets for grinding wheels, all such operations (impregnation, stabilisation) may be the cause of disorders in the geometry of their structures. Therefore special care concerning the elaboration of the technology of the net production is required.

The construction elements of a natural, flat spiderweb are stable, even at the crossing points. Different textile techniques may be used to connect the elements of the nets by retaining the basic rule of spiderweb type structure. These techniques are weaving, knitting, tying, plaiting crocheting, and their modifications.

Analysis of the possibilities of flat round net creation

The geometry and structure of a nets created by different techniques depend on the specificity of each production technique as well as of the single elementary links characteristic by which each of the techniques is distinguished.

A mapping of the web shown in *Figure 1* may be performed on the basis of the scheme shown in *Figure 2a*; whereas *Figure 2b, 2c, and 2d* show other propositions for the geometry formation of flat, round nets.

The common feature of a flat round spider's web is the existence of a central point, which is the starting point for the elements produced from it in the radial direction. One of the characteristic features of this kind of construction is an accumulation of these elements in the nearest surrounding of the central point. Fiks [1] studied the tensions appearing in grinding wheels. He carried out a model analysis of the tensions reduced on the diameter of a grinding wheels with a ceramic binding material (*Figure 3*). He proved that the highest tension appears on the inside surface of the fixation hole. An increase in the diameter value causes a decrease in the tension evoked by the centrifugal forces.

Tensions are lower on the outside abrasive surface than close to the hole (the central point). Due to this, in the case of net application in grinding wheels, the decrease in the density of nets by radial threads when the net diameter increases is the advantage of this system.

A net arranged similarly to a spider's web

The net shown in *Figure 2a* (arranged very like a spider's web) has a central point, which is the starting point for the warp threads arranged radially. The second system of threads, the weft threads is arranged spirally, this is continuous, which makes the production technology easier. Another way to build this structure is the arrangement of weft threads in the form of concentric polygons. In nets, not spun by a spider requires breaking the wefts and connecting their ends, which means an increase in production difficulties from a technological point of view; especially significant difficulties in obtaining a uniform structure occur due to the random working-in of the particular weft. That is why the following considerations concern the structure of continuous weft.

As *Figure 2a* shows, the system of threads in the net creates eyes that are trapezoidal in shape. The smallest eyes are in the middle part of the net, which grow, along with the distance, from the centre.

The easiest way to attach this structure may be the sticking or welding of the threads in the place of their crossing. However, it is possible to avoid these processes and place the net directly on the composite matrix.

The rhomboid net

As *Figures 2b, c, and d* show, the basic elementary structural shapes more or less differ from the trapezoidal shape, which is why there is a strong need for analysis of the geometry arising from the formation techniques in order to predict the potential application of these structures.

The classical flat net, which is shown in *Figure 4* (see page 56), has eyes in the shape of rhombus [4]. Their vertexes are the crossing points or the connection points of the threads with the other linear elements that create the net.

There is a possibility of creating a round net with eyes of a shape close to that of a rhombus, which is shown in *Figure 2b*. This net is made of one thread system that has its beginning at the central point.

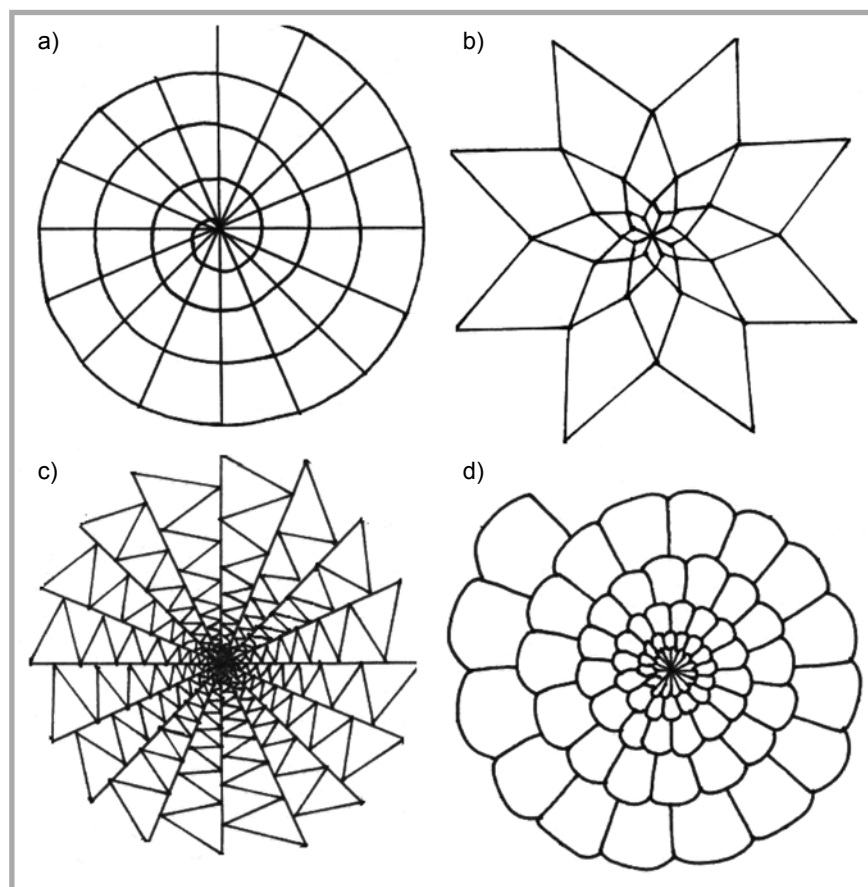


Figure 2. Schemes of the geometry of flat round nets; a – imitation of the structure of a flat spider's web, b, c and d – examples of the possible net geometries in order to recreate them with different textile techniques, b – a diamond-shaped net, c – a zigzag net, d – a spiral net.

Initially the threads run radially, but just after the first eye they change direction in the whole arrangement, which means that the next system of threads may be alternating or crossed, which is shown in **Figure 5**.

The eyes in this net have the shape of a deltoid. The round net with eyes of a rhomboid shape deviates significantly from its original spider web construction. Despite that some specific features of round webs like the central point and the growing dimensions of the eyes along

with the growing diameter of the whole net are preserved. One may presume that the behavior of such a net during radial loads will be disadvantageous. The forces working on the net will extort the „fold together” of the eyes, which leads to significant changes in the dimensions and structure of the net. Such a net shape may be used as a decoration or for the packaging of egg-shaped objects.

The zig-zag net

The structure shown in **Figure 2c** has radially arranged threads as in a classical

spider's web. The second system runs between neighboring radial threads to create a broken line. This structure may play a role in the strengthening of composite discs or other whirling elements under centrifugal forces.

The spiral net

The spiral net shown in **Figure 2d** is made of the one generating line that creates spiral loops hung on half of the vertex arc of the two loops of the previous spiral scroll. The dimensions of the eyes grow along with the distance from the central point. The special feature of this structure is the lack of a continuous system that runs radially, which is because the arms of the loop do not form a continuum. The spiral structure does not exist in a tensioned form because it transforms into a rhomboid structure.

Analysis of the influence of the creation technique on the geometry and structure of flat round nets

The spider web-type nets

It was stated that using weaving or knitting technology and the Japanese technique of net creation might produce the net that is presented in **Figure 2a**. There is no mechanical process (realised by a machine) of such web-type net production at the moment.

The weaving technique

The weaving technique allows to create a spiderweb-like structure (as **Figure 2a** shows) with a continuous weft, of a plain or gauze weave. The plain weave is the simplest of all, and additionally it produces short interlacings in both systems at the same time. The gauze weave allows to create a more stable structure with limited mutual displacement of threads. The middle part of this net (**Figure 6**) is relatively stable. Along with receding from the central point, the distances between the warp threads grow, and the stability of the net decreases.

Generally, a net of plain weave does not have a stable structure, which means that mutual displacement of the threads may appear under the influence of external loads. The advantage of this construction is the rectilinear, radial positioning of the warp threads [2].

As was mentioned above, the weaving technique gives mutual stabilisation to the

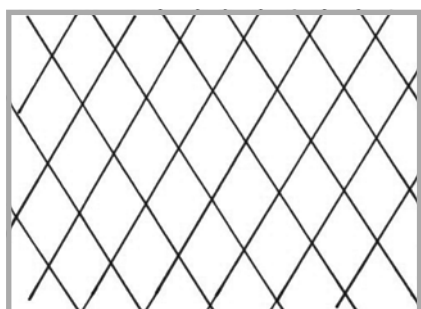


Figure 4. Flat net with eyes in the shape of a rhombus [9, 10, 12].

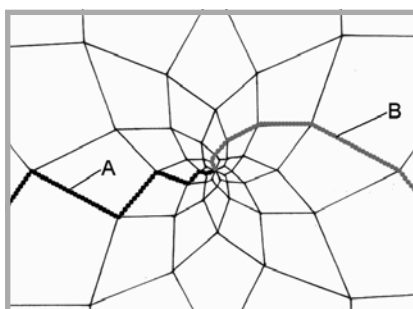


Figure 5. Scheme of thread arrangement in a rhomboid net; A – alternating, B – crossed.

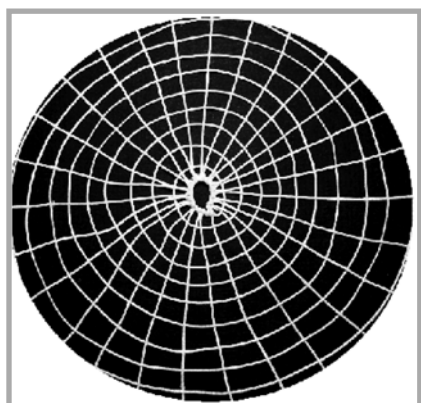


Figure 6. Round net of plain weave, handmade by the weaving technique, [13].

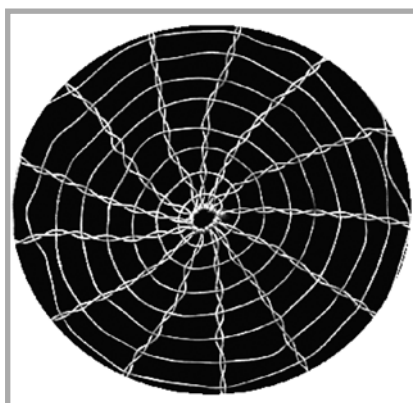


Figure 7. Round net of gauze weave, handmade by the weaving technique, [13].

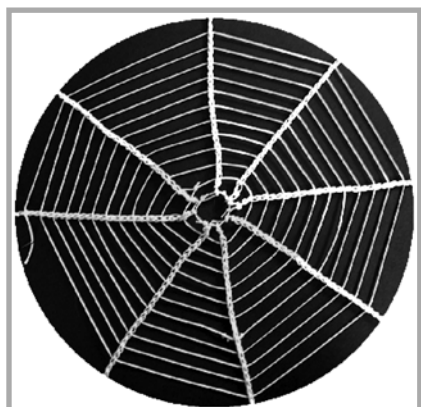


Figure 8. Handmade net made by the knitting technique with the fixation of the weft to the chain [13].

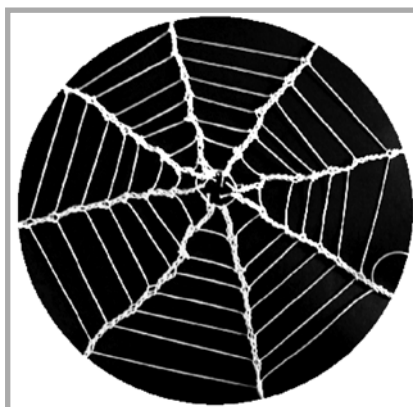


Figure 9. Handmade net made by the knitting technique with weft take-up in the eye of the chain [13].

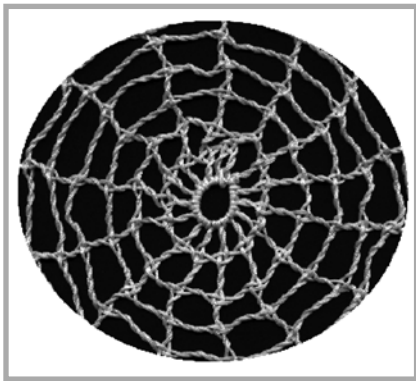


Figure 10. Round net made by the Japanese technique [13].

threads because of using gauze weave. The two basic gauze weaves – half- cross leno and full- cross leno – limit the possibility of a free increase in thread spacing because the growing length of the warp interlacements decreases the force of the weft fixation. Half- cross leno does not guarantee full stability of the net (**Figure 7**).

The knitting technique

Figure 8 presents a net of the spider web type (in knitting technique known sometimes also web) whose single elements are composed of a chain stitch with close eyes [8]. The weft is placed on the chain thread and under the needle. The character of this fixation is similar to the gauze weave. The second possibility consists in feeding the needle that creates the chain weft (**Figure 9**). The creation of a mechanism for the production of these structures is difficult but possible.

The Japanese technique

Created in Japan, this method consists of the simultaneous twisting and interlacing of threads. The Japanese net does not have knots. The connections are created as a consequence of the interlacing of twisted component threads that make up the sides of the eye [12].

The sides of the eye are created by two twisted threads. The crossing point fulfils the role of the single element in plain weave, which gives a stable connection. However, the substantially working-in of the thread forming the net, especially the radial elements, reject the application of this net in rigid composites. It can be assumed that this construction may be used in elastic elements of egg-line shape.

We also assume that such a structure could be mechanically produced by a modified plaiting technique.

The rhomboid net

The net presented in **Figure 2b** may be manufactured by the knotting (macramé) and Japanese techniques.

The knotting technique

The classical cube knot was used to make the model net. Its structure is presented in **Figure 11**. The handmade net made by the knotting technique is presented in **Figure 12**.

The central element of the web is a thread knotted in a round loop. This is the basis for the rest of the threads that will make the web. The eyes change their dimensions as in each of the round nets. Thanks to these knot connections, the net is stable. When the net is in a loose state, it gives the impression of being chaotic as the tension in the knots cause a curvilinear course of the thread in the eye. The application of low tension in the net is enough to observe that the eyes start to have a regular rhomboid shape. A stabilisation process is required to maintain this form. The knot connections create the thicker points on the net surface. However, it is possible to decrease the thickness by using other kinds of knots, for example a flat knot, but irrespective this, the knots will be the thick places of the structure.

The Japanese technique

The structure presented in **Figure 2b** may be created by the Japanese technique. A net made by the Japanese technique is presented in **Figure 13**.

The lack of knots and sharp bends of the threads at the place of their crossing gives a regular thickness to the structure, and the lack of tension does not deform the shape of the eyes. The act of twisting the net's elements can cause a change in the dimensions of the structure when it is loaded. One may presume that this kind of round nets may be easily used as supporting material for grinding wheels and cut-off disks but only after the stabilisation process.

This structure may be made by the plait method.

The zig-zag method

The net presented in **Figure 2c** may be produced by the knitting and knot method.

The knitting method

The radial elements of a net may be produced with a chain stitch, and the weft

may be fixed by the zigzag method. The eyes of the net have a rectangular shape, in which two sides are weft threads and the third side is made of the eyes of the chain. There are two ways of weft fixa-



Figure 11. Cube knot used in the macramé technique [10, 12].

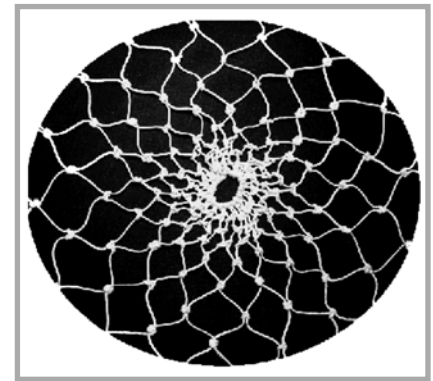


Figure 12. Round net made by the macramé technique [14].

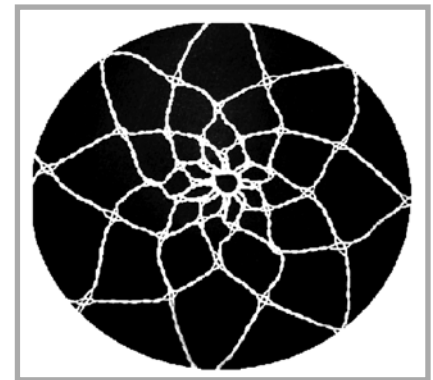


Figure 13. Round net made by the Japanese technique [14].

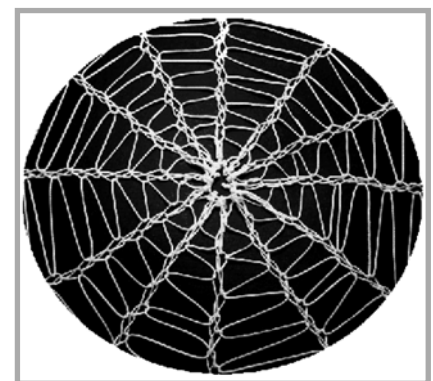


Figure 14. Zigzag net with the weft hung on the chain elements [13].



Figure 15. Round net made by the file method [15].

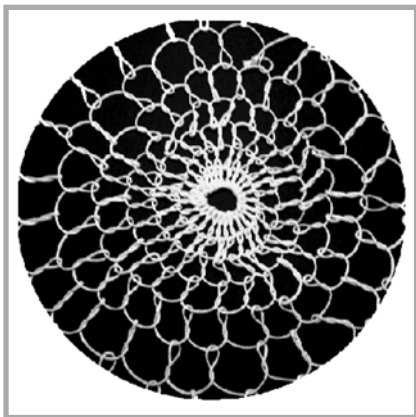


Figure 16. Round net made by the crocheting method [16].

tion: the first one consists in hanging the weft threads on the chain element – a similar effect is shown on **Figure 14** (see page 57). Please note that the structure presented in **Figure 14**, is made by techniques that connect the knitting technique (radial elements) and the sewing technique. The connection of wefts with radial elements is not stable. The second possibility consists in supplying the weft to the needle, which creates a chain working on two threads together, which will guarantee stable connections.

A zig-zag net made by the knitting technique is not a stable kind of net on account of the construction and the manner of fixation of the crosswise elements to the radial elements. Besides, thread damage in the chain causes the destruction of the net. A mechanisation process to produce these nets may be based on the wale knitting technique.

The spiral net

Examples of a spiral net in a loose state are shown in **Figures 15 and 16**. Probably these nets may have only decorative functions.

Summary

The new textile structures – flat round nets, arranged by the inspiration of a spider web, may find different applications. The Institute of Architecture of Textile at the Technical University of Łódź carries out studies on the properties of nets and the possibility of their mechanised production.



References

1. Fiks W.; 'The wear resistance of grinding disk', (in Polish), *Zeszyty Naukowe PŁ (Scientific letters, Technical University of Łódź) no. 895, Łódź 2002.*
2. Frontczak-Wasiak I., Snycerski M., Stempień Z., Suszek H.; 'Measuring Method of Multidirectional Force Distribution in a Woven Fabric', *Fibres & Textiles in Eastern Europe Vol. 12, Nr 2 (46), 2004, pp. 48-51.*
3. Jankowski E. Skupiński S.; *Materiały i wyroby ścierne*. Ed. WNT. Warszawa, 1971.
4. Konopa T.; 'Zagadnienia budowy, produkcji i eksploatacji sprzętu połowowego w świetle obecnej i przyszłościowej floty rybackiej w Polsce'. Part I, 'Flota obecna', Ed. Wydawnictwo Instytutu Morskiego, Gdańsk 1968r.
5. *Product guide of The Korsze Fishing Nets Factory.*
6. 'Nets and the armament of tools of the fishing', (in Polish), *Proceedings of the Symposium of the Sea Fisheries Institute, in Gdynia, 1980r.*
7. Oczko K. Porzycki J.; 'Szlifowanie – podstawy i technika', Ed. WNT. Warszawa 1986.
8. 'Rachelgewirkte Netze und Verpackungsmittel...'; *Kettenwirk – Praxis Nr 2, 1978r.*
9. Stolarek A.; 'Nets Structures', (in Polish), M.Sc. thesis, promotor M. Snycerski, Institute of Architecture of Textiles, Technical University of Łódź, 2006.
10. Turska J.; 'Ściegi makramy', Ed. Wydawnictwo Spółdzielcze; Warszawa 1984 r.
11. Winiarski J.; 'Technika połowu ryb' Ed. PWN Łódź 1970.
12. Woźnicka M.; 'Nets-type Open-Work-Products', (in Polish) M. Sc. thesis, promotor I. Frontczak-Wasiak, Institute of Architecture of Textiles Technical University of Łódź, 2003.
13. Polish patent P-383803 patent-notification, 19.11.2007.
14. Polish patent P-383804 patent-notification, 19.11.2007.
15. Polish patent P-383805 patent-notification, 19.11.2007.
16. Ziólek A., www.ziolek.pl/fotografie/2002-11.htm
17. www.seafa.brics.com

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